Active Final Approach Spacing Tool Development

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The throughput of the nation's busiest airports could be improved by more precisely spacing aircraft on final approach. More accurate final approach spacing ensures that the aircraft are safely separated, but that no avoidable gaps exist in the traffic flow. Ames Research Center and the Federal Aviation Administration (FAA) are continuing to design, develop, and plan deployment of a software-based decision support tool (DST), called the Final Approach Spacing Tool (FAST), to increase airport throughput. An early version of this DST, known as *Passive* FAST (pFAST) provides runway assignments and relative landing orders and is being deployed as part of the FAA Free Flight Phase 1 Program. Current research is focused on developing a future version of this DST, known as *Active* FAST (aFAST) that will allow air traffic controllers to achieve more accurate final approach spacing by providing heading, speed, and altitude commands.

Because of the extremely dynamic nature of air traffic situations, providing advisories to air traffic controllers requires a system whose decisions are reliable yet flexible. As a result, the aFAST system incorporates elements of fuzzy reasoning and rule-based decision making. Using these technologies, the basic implementation of a concurrent scheduling algorithm and a knowledge-based conflict-detection and resolution algorithm have been completed. These algorithms form the foundation of the aFAST system. They determine safe and efficient trajectories for arrival traffic by simultaneously sequencing aircraft along flightpath segments and by resolving all predicted conflicts among those aircraft. A patent application for these algorithms is being pursued in order to investigate their suitability for private and international ATC environments.

In order to evaluate the performance of the aFAST system, an innovative approach for its simulation was developed. Previous DSTs have focused, almost exclusively, on human-in-the-loop simulations to track the progress of their development, since no other reliable method of executing the advisories was available. The aFAST system will use a three-tiered testing process consisting of trajectory tracking, advisory tracking, and human-in-the-loop simulation. During trajectory tracking, aFAST uses its own solution trajectories to simulate radar tracks. The aircraft's initial positions that are used to determine an initial solution trajectory are specified in order to represent a complex traffic flow. Subsequently, each solution trajectory is used to simulate the next aircraft position, which is used to determine the next solution trajectory. This scenario allows the stability and performance of the aFAST system to be analyzed in an environment free of both prediction and flight technical errors. During advisory tracking, aFAST electronically issues its advisories to an independent Pseudo Aircraft Simulation (PAS). PAS automatically executes these maneuvers using its own independent set of aircraft and atmospheric models. This scenario is suitable for investigating the effects of prediction errors. Finally, during human-in-the-loop simulations, air traffic controllers issue advisories to human pseudo-pilots that respond using PAS. This most realistic scenario can be used to study the effects of both prediction and flight technical errors, as well as to explore the usability and

suitability of active advisories for achieving more accurate final approach spacing.

The aFAST system has used trajectory tracking to control several hours of flights to an airport with a single arrival runway. During these intentionally busy traffic scenarios, the aFAST system achieved safe and precise separation of the aircraft. In the near term, work will focus on the trajectory tracking and advisory tracking

methods of testing. These techniques will be used to (1) quantify the aFAST system's sensitivity to prediction and flight technical errors and (2) assess the benefits of active advisories. Finally, preparation for more complex multi-runway scenarios will begin.

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An Analysis of the Radar Reflectivity of Aircraft Wake Vortices

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Large aircraft shed strong vortices in their wakes which pose a hazard to following aircraft. Therefore, during landings in bad weather (that is, under instrument flight conditions) strict spacing is maintained between aircraft. These spacings are usually too conservative, and it has been estimated that several billion dollars could be saved annually by the airlines if the spacing could be reduced by 2 kilometers (km) from the current separations of 5.5 to 11 km. The objective of this work was to assess the potential of ground-based radar for detecting the vortices.

What is needed is a wake sensor that is relatively inexpensive, has long range, requires little or no maintenance, and works in all weather conditions. No sensor currently meets these requirements. Because the pressure in the eye of an aircraft vortex is low (and thus has a low index of refraction), the air in the eye reflects radio waves. A scattering analysis revealed that the peak reflectivity occurs at a frequency near 50 megahertz (MHz) (see fig. 1) and is strong enough that a vortex could

be detected at a range of 3 km with an average power of about 400 watts. A frequency of 50 MHz has several advantages: (1) clutter from rain and fog is not an issue and so the system would work in all weathers; (2) inexpensive and low-maintenance radars already operate at 50 MHz for measuring atmospheric winds and they could be modified to track vortices; and (3) if the system is supplemented with sound waves to enhance reflectivity (via the so-called Radio Acoustic Sounding System technique), the required sound frequency is low enough that attenuation of the sound wave (which would limit range) is not a problem. The main disadvantage of the system is size of the antenna system. A typical set-up might have a 10 by 10 array of small TV-like antennas spaced 3 meters apart on the ground. Such a system cannot be physically pointed. Rather, phase differences would be utilized for pointing.

A provisional patent has been filed and a flight test is being planned to verify the predicted reflectivity near 50 MHz.